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Undersea Biomedical Research, Submarine Supplement 1979

Cardiovascular risk factors in submariners

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Tappan, D. V., L. W. Mooney, M. J. Jacey, and E. Heyder. 1979. Cardiovascular risk factors in submariners. Undersea Biomed. Res. Sub. Suppl.: S201–S215.—A sizeable group of biochemical, hematologic and physiologic variables that significantly affect the prognosis for diseases of aging, especially for coronary heart disease (CHD), were studied in 1017 submariners. Skinfold thickness in these subjects was determined to be higher than in most other groups of men of similar age; the total level of body fat was within the range of high normality. Serum cholesterol levels, cigarette smoking, relative weight, and blood pressure appeared to be the factors most directly responsible for the extent of cardiovascular risk in this group of submariners. Though submariners as a group do not apparently have appreciably higher levels of CHD risk than other American men, there was a significant tendency for total risk to increase with length of submarine service as well as with age. A similar age-independent increase in serum cholesterol correlating with length of submarine service was reported earlier. Split-sample analyses support the reliability of the age-corrected correlations of CHD risk with time of submarine service. Although no attempt was made to prove a direct relationship between alcohol consumption or coffee drinking and cardiovascular risk, there were strong correlations noted. These factors, combined with serum cholesterol levels, cigarette smoking, and relative weight, deserve consideration as potentially modifiable CHD risks.

cardiovascular risk factors
submarine service
military personnel
cigarette smoking
coffee consumption
serum cholesterol
body weight
alcohol consumption
blood pressure

In earlier studies, the amount of time spent on active submarine duty was shown to have several biochemical influences in Naval personnel (Tappan, Jacey, Heyder, and Tansey 1975; Tappan, Jacey, Heyder, and Harvey 1979). The principal biochemical effects of submarine life on volunteer submariners were trends toward increased serum cholesterol concentrations and increased rate of utilization of glucose after a loading test. Both of these changes were apparently related directly to years of submarine service, since they occurred in addition to the changes in these serum components attributable to age. Since serum cholesterol is a prominent member of a group of factors associated with risk of cardiovascular disease (Levy and Ernst 1973; Moore 1973) and an exaggerated insulin response to a carbohydrate load may presage the development of diabetes mellitus (Hoffman 1964), additional investigations of these and related factors seemed warranted for the same healthy submariner population.

In this paper, we have examined the relationship in 1017 submariners of several hematologic, biochemical, and physiologic variables that have significance for the prognosis, prevention, or treatment of diseases of aging, with particular reference to factors associated with a risk of coronary heart disease.

Though the study was designed to evaluate the effects of submarine duty through a series of re-examinations of the individual subjects, this report is concerned with comparisons of the data obtained at the initial examinations of the subjects. We present evidence that there is a measurable risk of cardiovascular disease related to length of submarine duty in addition to the risk attributable to increasing age. Several factors, including coffee and alcohol consumption and cigarette smoking, appear to contribute to this risk.

METHODS AND MATERIALS

The group of 1017 active-duty submariners participating in this study and the extensive series of medical and laboratory examinations performed on these subjects were described previously (Sawyer with Baker 1972; Tansey 1974; Tappan et al. 1975, 1979). The examination program was initiated to provide background data on the health status of the general submariner population and to provide preliminary indications of the effects of living within the closed environments of modern submarines. Of the subjects volunteering for the study, 84.9% were members of the crews of 23 operational submarines; the other subjects came from nine shore-based rotation assignments. All were qualified submariners; 85.7% were enlisted personnel and 14.3% were officers. For our comparative studies, data pertinent to coronary heart disease (CHD) and related risks were obtained from the medical and anthropometric portions of the two-day series of tests given to each subject and from the biochemical and hematologic segments of this multiphasic study. The data for time on nuclear patrol were available directly from the health records of the men since it is mandatory that records be kept of time of potential exposure to radiation aboard nuclear submarines.

For an estimation of the CHD risk among the subjects examined, the multiple logistic model of Truett, Cornfield, and Kannel (1967) based on discriminant function analysis of 12-year follow-up data from the Framingham study of cardiovascular disease incidence was used. To calculate the level of cardiovascular risk for all of our subjects less than 40 years of age, we have used the constants in the risk-estimating equation derived by Halperin, Blackwelder, and Vetter (1971) for their lowest age group (30–39 yr). Their values for the 40–49 age group were utilized for our subjects aged 40 and above. Included in our risk calculations are data for serum cholesterol (mg/dl), systolic blood pressure (mmHg), relative weight (weight/median weight per height group × 100), cigarette smoking (0 = none, 1 = < 1, 2 = 1, 3 = > 1 packs/day), ECG (1 = normal, 2 = abnormal), hemoglobin (g/dl), and age (Halperin et al. 1971).

RESULTS

We present in Table 1 the frequency distributions, means, and standard deviations for a group of factors associated directly or indirectly with cardiovascular risk and for two overall estimates of risk in the submariners. Data for age, total submarine experience, serum cholesterol, and hemoglobin used in the calculations reported here were included in a previous publication (Tappan et al. 1979).

To provide frequency data so that the reader can make further calculations of population statistics, the distributions are shown in tabular rather than graphic form. The high and low

TABLE 1

FREQUENCY DISTRIBUTIONS OF POTENTIAL CORONARY HEART DISEASE RISK FACTORS IN SUBMARINERS

	Low Ref	High Ref	<=1	1	2	3	4	5	6	7	8	>8	Mean	SD
% Fat	8	32	31	48	87	135	210	199	170	78	23	7	19.5	5.8
Abdomen	70	118	9	76	144	233	231	148	104	44	17	10	90.1	10.4
Ht Wt	11.2	14.0	9	49	99	191	236	227	124	57	18	6	12.6	0.6
Skinfold	12	84	9	66	137	150	140	101	67	26	8	9	40.6	16.0
Rel Wt	0.72	1.44	6	44	166	267	248	147	82	38	15	3	1.01	0.14
Smoking	0	4	338	126	128	199	103	68	37	14	4	0	0.89	0.90
Systolic	100	148	6	39	149	276	307	159	53	18	7	3	118.9	8.7
Diastolic	48	96	9	9	81	214	285	267	119	21	8	4	70.2	8.2
Rate	50	106	4	7	54	180	295	241	165	49	19	3	78.3	9.9
Coffee	0	14	246	89	145	110	114	55	98	120	40	0	4.8	4.3
Alcohol	0	64	87	421	222	100	72	31	20	30	10	24	14.4	17.6
Risk	0.1	6.5	349	415	103	47	30	19	8	8	11	27	1.12	3.60
Risk>28	0.1	6.5	41	197	89	44	29	18	8	8	11	27	2.14	5.09

Values are means ± SD. % Fat = percent body fat; Abdomen = abdominal circumference, cm; Ht/Wt = ponderal index, height (inches)/weight (lbs)$^{1/3}$; Skinfold = sum of infrascapular and triceps skinfold thickness, mm; Rel Wt = relative weight, median weight/2" height groups; Smoking = total cigarettes, packs/day; Systolic = systolic blood pressure, mmHg; Diastolic = diastolic pressure, mmHg; Rate = pulse, beats/min; Coffee = total coffee, cups/day; Alcohol = total alcohol, drinks/week; Risk = calculated %risk/12 years, entire population (Halperin et al. 1971); Risk>28 = calculated %risk/12 years, men 28 years of age and older.

reference data values for each of the rows are presented in the first two data columns of the table. The data range between each pair of reference values is divided into eight equal intervals, with the population count falling within each interval shown in columns 1 to 8. The number of subjects having values below and above the reference values are indicated in columns < = 1 and > 8. Figure 1 provides an illustration of the data, showing graphically the distribution of the calculated risk of CHD among the subjects over a 12-year period.

The blood pressure data in Table 1 represent the means of 4 measurements each for systolic and diastolic pressures, 2 in the sitting, and 2 in the supine position. Pulse rate is a mean value from 2 determinations made at rest in the sitting position. Since total smoking, alcohol intake, and coffee drinking data were recorded for the date of the test and for each preceding 5-year interval, the totals for these variables were calculated by: current value + 1/5th of value 5 years ago + 1/10th of value 10 years ago (Sawyer with Baker 1972), and so forth. Such a calculation is based on the work of Cornfield and Mitchell (1969), who concluded that although the increased risk of cardiovascular disease associated with smoking disappears rapidly with time after smoking is stopped, the risk does not disappear completely for at least a decade. Though we assumed residual effects similar to smoking effects for alcohol and coffee consumption, we found concurring results when carryover was not included in the data. To include cigarette smoking in the calculation of CHD risk, only the amount of smoking at the time of the examination was used, to conform to the risk-estimation procedure employed (Truett et al. 1967; Halperin et al. 1971).

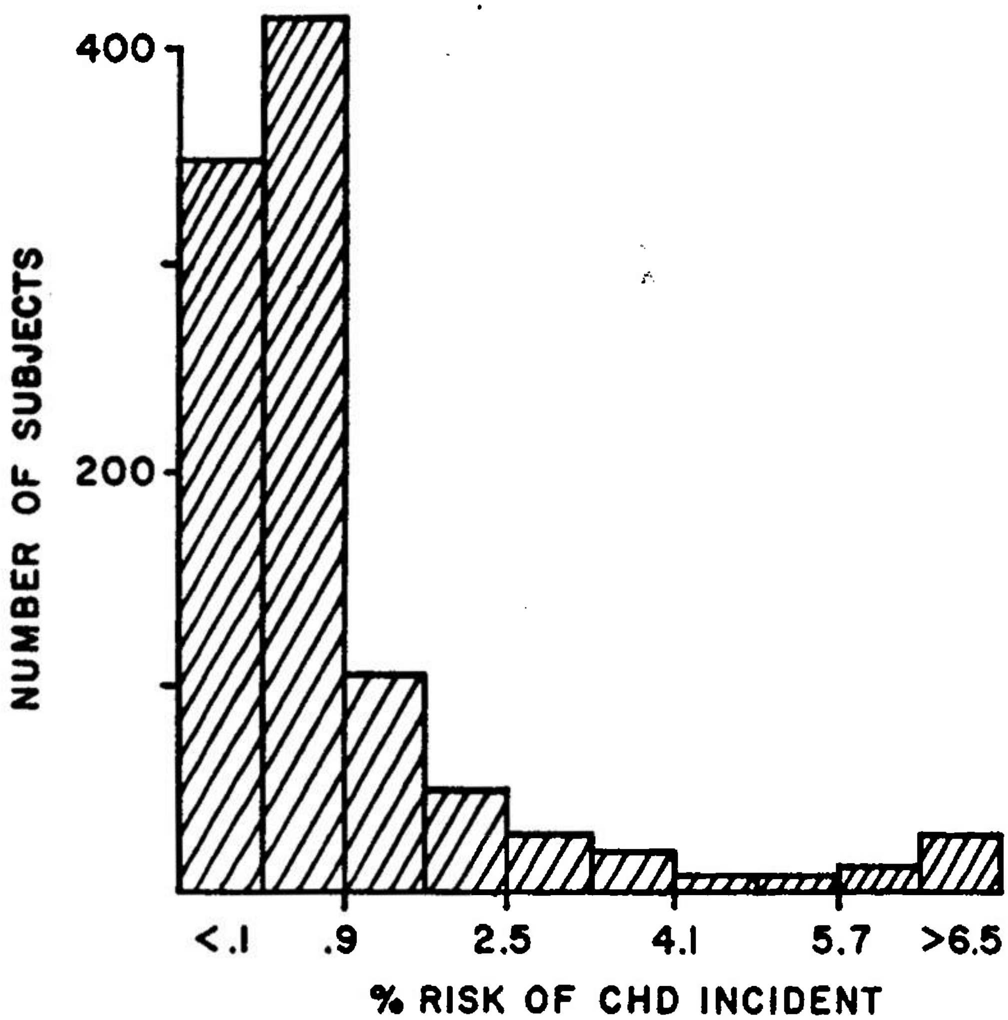

Fig. 1. Frequency distribution illustrating percent chance of CHD incident within 12 years in 1017 submariners.

Although each of the measures of general body fatness gives a somewhat different estimate of the status of any individual, there was significant agreement among the various estimates. The correlation coefficients of relative weight, which is used in the calculation of risk, against the other estimates of body bulk or fatness are 0.975 (vs. percent fat), 0.888 (vs. abdominal circumference), −0.938 (vs. ponderal index), and 0.567 (vs. sum of skinfolds). All correlations were significant at $P < 0.001$ (Snedecor and Cochran 1967).

Table 2 shows correlations of the known and possible risk factors and of summarized risk against age, submarine qualification time, service time, and time exposed to closed submarine environments. Correlations are also presented in comparison to submarine time, patrol years, and service time, each corrected for age effects.

Except for the nonsignificant correlations with values for ECG abnormalities and systolic blood pressure, somewhat higher correlations were obtained against total service time than

TABLE 2
CORRELATIONS OF POTENTIAL CORONARY HEART DISEASE RISK FACTORS WITH AGE, SUBMARINE QUALIFICATION TIME, AND MILITARY SERVICE TIME IN SUBMARINERS

Factor (1)	Age (2)	Subm (3)	Nuke (4)	Serv (5)	R13.2*	R14.2	R15.2
Age	—	0.835†	0.546†	0.951†	—	—	—
Smoking	0.148†	0.166†	0.098‡	0.191†	0.078§	0.021	0.164†
Chol	0.317†	0.299†	0.199†	0.301†	0.065§	0.033	0.029
Systolic	−0.015	0.000	0.055	0.011	0.023	0.075§	0.081‡
Hb	−0.050	−0.043	−0.029	−0.029	−0.002	−0.002	0.060
Rel wt	0.221†	0.208†	0.127†	0.237†	0.044	0.007	0.089‡
ECG	−0.052	−0.026	−0.013	−0.043	0.032	0.018	0.021
Risk	0.456†	0.424†	0.304†	0.445†	0.088‡	0.073§	0.041
Diastolic	0.274	0.231†	0.188†	0.284†	0.004	0.048	0.078§
Rate	0.099‡	0.068§	0.032	0.109†	−0.027	−0.026	0.048
Coffee	0.558†	0.490†	0.321†	0.564†	0.053	0.023	0.130†
Alcohol	0.106†	0.122†	0.013	0.124†	0.061	−0.054	0.075§

Values are correlation coefficients. *For risk factors, see Table 1 footnotes; Age = years; Subm = years since submarine qualification; Nuke = years on nuclear submarines; Chol = cholesterol, mg/dl serum; Serv = years of military service; Hb = hemoglobin, g/dl; ECG = electrocardiogram abnormalities; *R13.2 = correlation of variable in column 1 and submarine time (3) factored for age (2); †$P < 0.001$, ‡$P < 0.01$, §$P < 0.05$.

against time of submarine qualification or time on nuclear patrol. After removal of the effects of age (Snedecor and Cochran 1967), cholesterol levels, ECG abnormalities, and total risk levels had a higher correlation against submarine time than against the other two variables. Other risk factors had a higher correlation against total service time.

Table 3 indicates correlations of the hematology and chemistry variables measured against the selected list of potential risk variables presented in Table 2. Partial correlation calculations (Snedecor and Cochran 1967) were used to correct for the effects of both age and submarine service time in these data; only those correlations that were significant at $P < 0.05$ are shown. It is apparent from the data that the erythrocyte elements, hematocrit and hemoglobin, as well as the total leucocytes, neutrophils, and lymphocytes correlated significantly with several of the potential risk factors. Total erythrocyte counts were not available among these data. Since relative or percent lymphocytes generally decrease as neutrophils increase in standard differential white cell counts, it should be noted that correlations of relative lymphocyte counts against the risk factors tended to be negative (data not shown) compared to the significant positive correlations recorded for calculated total cell numbers (Table 3).

For the most part, 2-h postprandial glucose data correlated positively with risk factors. Fasting and postprandial glucose as well as uric acid, cholesterol, total protein, globulin, and two of the enzymes correlated negatively with the amount of coffee consumption. Variations in hematocrit, hemoglobin, total leucocyte counts, serum phosphate, urea, uric acid, cholesterol, total protein, and alkaline phosphatase tended to occur in concert with changes in total calculated risk.

Table 4 shows the means for total risk and actual or possible risk factors for the subjects in five-year age groups between ages 18 and 48. These distributions are presented to allow comparisons with data from several previously published studies in which such factors were

TABLE 3

Correlation of Hematology and Serum Constituents with Potential Coronary Heart Disease Risk Factors Corrected for Age and Submarine Qualification Time

HCT		
	smoking	0.137†
	alcohol	0.086‡
	systolic	0.065§
	diastolic	0.171†
	rate	0.181†
	chol	0.129†
	rel wt	0.188†
	risk	0.129†
HB		
	smoking	0.081§
	diastolic	0.116†
	rate	0.159†
	chol	0.107†
	rel wt	0.149†
	risk	0.087‡
WBCS		
	smoking	0.295†
	coffee	0.126†
	alcohol	0.078§
	rate	0.197†
	chol	0.065§
	risk	0.077§
NEUT		
	smoking	0.239†
	coffee	0.089‡
	alcohol	0.110†
	systolic	0.076§
	rate	0.225†
TLMP		
	smoking	0.179†
	coffee	0.094†
	chol	0.065†
GLUC		
	coffee	−0.065§
	diastolic	0.069§
2HPP		
	coffee	0.114†
	systolic	0.079§
	diastolic	0.109†
	rate	0.073§
	chol	0.076§
	rel wt	0.122†
CA		
	coffee	0.076§
	alcohol	0.085‡
	systolic	0.111†
	diastolic	0.132†
	rate	0.076§
	chol	0.143†
PHOS		
	smoking	0.105†
	coffee	0.182†
	alcohol	0.071§
	chol	0.180†
	risk	0.254†
BUN		
	smoking	−0.110†
	alcohol	−0.064§
	chol	0.096‡
	risk	0.121†
UA		
	coffee	−0.108†
	chol	0.267†
	rel wt	0.077§
	risk	0.266†
CHOL		
	coffee	−0.196†
	systolic	0.167†
	diastolic	0.089‡
	rate	0.085‡
	rel wt	0.156†
	risk	0.426†
TPR		
	smoking	−0.116†
	coffee	−0.071§
	alcohol	0.063§
	systolic	0.068§
	diastolic	0.152†
	rate	0.136†
	chol	0.262†
	risk	0.091‡
ALBN		
	smoking	−0.068§
	systolic	0.072§
	diastolic	0.113†
	rate	−0.066§
GLOB		
	smoking	−0.063§
	coffee	0.101‡
	alcohol	0.097‡
	diastolic	0.073§
	rate	0.173†
	chol	0.149†
	rel wt	0.074§
A/G		
	smoking	0.065§
TBIL		
	smoking	0.137†
	coffee	0.079§
ALKP		
	coffee	−0.071§
	rate	0.078§
	chol	0.343†
	rel wt	0.081§
	risk	0.316†
LDH		
	smoking	0.075§
	alcohol	0.063§
	rate	0.115†
	rel wt	0.172†
SGOT		
	coffee	−0.075§
	alcohol	[illegible]
	diastolic	0.106†
	rate	0.195†
	chol	0.149†
	rel wt	0.194†
SP GR		
	alcohol	−0.103‡

Values are correlation coefficients. For risk factors, see Table 1 and 2 footnotes; HCT = hematocrit; HB = hemoglobin; WBCS = white blood cells; NEUT = neutrophils; TLMP = total lymphocytes; GLUC = fasting glucose; 2HPP = 2-h postprandial glucose; CA = calcium; PHOS = inorganic phosphorus; BUN = urea nitrogen; UA = uric acid; CHOL = cholesterol; TPR = total protein; ALBN = albumin; GLOB = globulin; A/G = albumin/globulin ratio; TBIL = total bilirubin; ALKP = alkaline phosphatase; LDH = lactic dehydrogenase; SGOT = aspartate aminotransferase; SP GR = urine specific gravity.

†$P < 0.001$; ‡$P < 0.01$; §$P < 0.05$.

TABLE 4

CORONARY HEART DISEASE RISK AND RISK FACTORS PER AGE CATEGORIES IN SUBMARINERS

Age Group	Number	Risk	Smoking	Coffee	Alcohol	Relative Weight	Chol	Hb	Systolic	ECG
< 23	204	0.2	0.69	1.68	12.82	0.979	193.4	16.1	119.1	0.039
23–28	341	0.3	0.72	3.29	12.47	0.992	199.2	15.9	118.9	0.015
28–33	208	1.2	1.14	7.01	16.19	1.031	216.4	16.1	118.4	0.034
33–38	201	2.1	1.30	7.00	16.73	1.055	222.5	15.9	119.3	0.015
38–43	53	3.7	[illegible]	8.88	17.49	1.061	219.4	15.6	117.5	0.000
> [illegible]	8	[illegible]	[illegible]	[illegible]	22.70	1.017	244.5	15.5	117.9	[illegible]

Values are means; for risk factors, see Table 1 and 2 footnotes.

discussed with respect to subjects' age. Though the small number of subjects in the oldest age group appeared in some cases to disrupt the age-related trends, various generalizations may be made concerning the changing levels of the risk factors as the population aged. Cholesterol concentrations and relative weight that appear in the risk-estimating equation (Halperin et al. 1971) showed unmistakable tendencies to increase with age, and they thereby increased the overall calculated levels of risk. Amount of cigarette smoking increased among the younger subjects for the first 15 ± 5 years of service, and then began to decrease among the older subjects. On the other hand, hemoglobin concentrations, systolic blood pressures, and ECG abnormalities (which are actually non-numeric in nature) were not age-dependent, according to this evaluation. Both total alcohol consumption and coffee drinking clearly increased with submariners' age.

DISCUSSION

Several aspects of the data for these one thousand apparently healthy men aged 18–48 are worthy of serious consideration. From the previous investigation of biochemical findings in these subjects, it was concluded that most of the data fell within ranges considered normal (Tappan et al. 1975), and it is not surprising that, with some exceptions, the same observation can be made concerning the factors analyzed in our report. It is important, however, to point out that statistically normal ranges for biochemical or physiologic variables for populations in this country do not necessarily specify the conditions conducive to optimal health, and that individuals are at varying degrees of risk for serious health problems that require identification and amelioration. An evaluation of the extent of existing risks provides a logical foundation for instituting programs designed to prevent or lessen such risks.

The relative weight or fatness of the subjects in this study was evaluated not only because of the significance of the relative weight of an individual to CHD risk (Truett et al. 1967; Halperin et al. 1971; Kannel, Castelli, McNamara, McKee, and Feinleib 1972), but also because of the importance to the submarine Navy of an answer to the question of whether habits and routines that develop aboard submarines during patrol lead to weight gain in operational personnel. Accurate information regarding the degree of fatness in the subjects is also important in relation to the general level of deconditioning of physical fitness experienced by submariners during deployment. It is also of considerable significance in determining whether the length of time spent on submerged patrols is more critical to the accumulation of occupational effects in this unique vocation than total time since qualification for submarine duty. The mode of living aboard submarines that tends to promote minimal physical activity and the consumption of generous diets, either of which promotes weight increases, may serve as models for the study of the effects of living habits that predominate in the American population.

Since there is little controversy over the fact that "the real culprit to good health is not total body weight, but relative or percent fat" (Wright and Wilmore 1974), many methods have been proposed to estimate the degree of fatness or obesity in human subjects. The indirect estimate of percent body fat calculated from our data by the procedure of Wright and Wilmore (1974) yielded a mean value of 19.5 ± 5.8% (SD) fat for the submariners. We chose the simpler of the methods described by these authors, which employs weight and abdominal circumference and correlates highly ($r = 0.88$) with measured data obtained by underwater weighing methods, to avoid errors in the use of their alternate procedure using skinfold data because of differences in the calipers used. Results for a similar population indicated 16.5 ± 6.2% body fat for 297 randomly selected marines with an average age of 28.7 years (Wright and Wilmore 1974). A survey also showed 14.3, 14.6, 15.3, 15.5, and 18.7% fat for civilian males, 23.3% for an Air Force population, and 12.5, 17.4, and 20.5% in Army personnel, all for ages in the range of the men in our study (Wright and Wilmore 1974). Though the spread of available data indicates the possibility of considerable experimental error, we concluded that the relative fatness of the submariners tended toward high normal ranges but did not greatly exceed that of many similar groups of healthy young men.

Among the other indexes of general body conformation, the sum of skinfold measurements from the upper arm (triceps) and subscapular (infrascapular) regions indicated a considerable excess of skinfold thickness in the subjects of this study compared to other population groups. While the overall mean for this group of submariners was 4.0 ± 1.6 cm, a similar mean for a probability sample of men aged 18–79, representing the non-institutionalized population of the United States (Stoudt, Damon, McFarland, and Roberts 1973), has been reported to be 2.8 cm, with means of 2.4 to 3.0 cm for the age categories between 18 and 54 years. All groups of men, including foreign and domestic populations, Army personnel, and former Naval aviators, whose data are summarized in the National Center for Health Statistics (NCHS) Report (Stoudt et al. 1973) have considerably smaller skinfold measurements than the subjects of the current study. Means or median values range from 1.3 to 3.4 cm for the various groups.

Researchers involved in making skinfold measurements emphasize that differences invariably arise from variations in the technique of different investigators and the use of different calipers (Meyer 1973; Stoudt et al. 1973). A comparison of skinfold data for 46 men measured by three different types of caliper showed mean values of 1.69, 1.84, and 2.19 cm for infrascapular skinfolds and 1.07, 1.13, and 1.27 cm for triceps skinfolds using the Harpenden, Lange, and Minnesota calipers, respectively (Stoudt et al. 1973). This 30% variability among instruments does not seem sufficient to explain the discrepancy between the data of the present study and those reported earlier, especially since we employed Lange calipers, which produce mid-range values. From such considerations, we concluded that submariners frequently have skinfold thicknesses in excess of those of men of comparable groups.

In a further comparison of the skinfold data reported for the NCHS survey (Stoudt et al. 1973) with similar measurements from our study, our means were 1.90 ± 0.82 and 2.16 ± 0.95 cm for triceps and subscapular skinfolds, respectively, while means for the NCHS survey were 1.1 and 1.4 cm. Hence the two measurements seem to account about equally for the increases in the sum of skinfold thickness reported for these subjects.

With the mean abdominal circumference among our subjects equal to 90.1 ± 10.4 cm and the mean value for the men of the NCHS survey 88.9 cm, with 90% of the population falling between 72.1 and 109.0 cm (Stoudt et al. 1973), there is no reason to conclude that there was a significant difference between submariners and American men for this measure of body size.

The ponderal index establishes a leanness-stockiness scale and is considered by some investigators to be the single best measure of body build (Meyer 1973; Stoudt et al. 1973). The mean index value for men of the United States in 1960–1962 was 12.40, ranging from 12.67 for men 18–24 years to 12.32 for 35–44 years (Stoudt et al. 1973). In the present study the mean of 12.6 ± 0.6 indicated no remarkable difference, according to this criterion, between submariners and other American men. Since the values for this index fall within a very narrow range, the mean value of 12.73 ± 0.63 found for U.S. Army men (Stoudt et al. 1973) may indicate a slightly greater degree of leanness in Army subjects compared to submariners. (Note that the index increases as relative fatness decreases.)

To consider the contributions of the various factors to the risk of cardiovascular disease, an assumption was made concerning the applicability of the analysis of risk to our subjects according to the multivariate logistic procedure. The original model of Truett et al. (1967), based on data for seven parameters measured for the subjects of the Framingham study, was later modified by Cornfield and Mitchell (1969) to include only five variables. The procedure was further refined by Halperin et al. (1971), who used a maximum likelihood method for arriving at parameter constants and again used seven variables to define risk. The generality of the latter approach was verified by Brand, Rosenman, Scholtz, and Friedman (1976) for application to cardiovascular disease incidence data collected over 8½ years in the Western Collaborative Group Study. In that study, correlation coefficients of 0.82–0.89 were found between predicted and actual occurrence of cardiovascular disease. Though high correlations ($r = 0.941$) were obtained for our data between the five-variable and the seven-variable analyses, the maximum likelihood constants of Halperin et al. (1971) were used to obtain the risk estimates reported here because of the confirmation (Brand et al. 1976) of the validity of this approach. The value of the procedure used here was emphasized by Gordon and Kannel (1971) and by Kannel (1974) who considered this the method that practicing physicians should use to evaluate risk levels in their patients realistically.

One rather profound alteration in the design of the multivariate analysis of risk was required to accommodate part of the data from our study. Since the risk of cardiovascular incident was collected from the Framingham subjects for population groups aged 30–39, 40–49, and older, it was necessary to use the values for the lowest age group (30–39) to evaluate our subjects aged 19–30 and 30–39. The equation coefficients for ages 40–49 were used for calculations made for subjects over 40. Since the mean age for the subjects was 28.4 years, an overapproximation of risk seems to have been made for about half of the subjects. When calculations were performed for the older half of the subjects 28.0 years or above, for whom all constants apply with reasonable accuracy, the mean risk was 2.14 ± 5.09 per 100 over 12 years compared to an approximate risk of 1.12 ± 3.60 for the group as a whole. It may be seen from the data of Table 4 that despite a probable overestimation of risk for the younger members of the group, a steady increase in risk occurred for the subjects during their careers of submarine duty. With our present level of information, we can only determine within a wide margin of uncertainty whether the men experienced a cardiovascular risk different from that of comparable populations in other occupations. Large standard deviations in all of the estimates reported here indicate fairly serious risks for a few individuals, which by this model may reach 15–20 chances per 100 over the 12-year risk period. Despite the possible overestimation and any psychological damage that might be inflicted, the potential for modifying risk (Gordon and Kannel 1971; Froelicher and Lancaster 1973; Kannel, Hjortland, and Castelli 1974) makes examinations and risk estimates (such as those performed here) potentially important for a population as young and vigorous as submarine service members.

The data presented in Table 2, which relate known and possible risk factors to length of time since qualification for submarine service, number of years aboard nuclear submarines, and total time of military service, furnish partial answers to the question of whether duty time spent in the closed environment of modern submarines is primarily responsible for any health-related effects among the subjects. The data for length of exposure to closed submarine environments are only pertinent to time spent aboard nuclear submarines, since similar information concerning time spent on diesel submarines was not available. Also, diesel submarines operate by periodically adding fresh air to the submarine environment and are almost obsolete in the U.S. Navy.

Table 2 indicates that for most of the known or possible cardiovascular risk factors there is a higher correlation with total military service time than with time since qualification for submarine service. In general, the correlation for time spent on submerged patrols was lower. The strong correlations of the risk factors with age, however, suggest the importance of examining correlations that have been corrected for age (Snedecor and Cochran 1967). With a few notable exceptions, such data, presented in the last three columns of Table 2, indicate that the risk factors have the highest correlations with total military service time. Submerged patrol time had the lowest correlations, with relationships to submarine time generally intermediate. The exceptions to these generalizations need special consideration.

Particularly prominent among the age-corrected correlations of the risk factors is the apparently significant ($P < 0.05$) correlation of cholesterol level with time since qualification for submarine service. This relationship, reported earlier (Tappan et al. 1979), appears stronger than that to military service time, and the increased association cannot be directly related to time spent on submerged patrols. Total calculated risk, partly but not entirely because of its dependence on cholesterol level, also seems to correlate most highly with length of submarine service. If these relationships to submarine time are verified by other studies, various stressors in the life of submariners, such as the alteration in routine between on-board submarine duty and ashore 'recovery' periods or the unique work/rest schedules on patrol, and the specific diet and activity patterns, may be shown to augment these effects significantly.

Despite the significant correlations of serum cholesterol levels and risk against submarine time demonstrated here and in our other paper (this Supplement) (Tappan et al. 1979), we wish to sound a note of caution in interpreting the data because of the method used to choose subjects for the study (Sawyer with Baker 1972; Tansey 1974). Although the subjects included submariners of various ages, lengths of service, and occupational specialties, it was not proved that these men represent an unbiased cross-section of submarine service personnel.

A split-sample correlation analysis performed as a check on the significance of the increase in age-corrected cardiovascular risk with length of submarine service, however, helped confirm the reliability of the data. For the verification test, the population was divided according to a random selection procedure; a complete set of correlation analyses was performed for each of the two subgroups. The correlations against submarine time, after correction for the influence of age, for the two subpopulations containing 49.7 and 50.3% of the available subjects were 0.192 and 0.222, respectively. The significance ratio of 0.412 clearly indicates that the two groups cannot be considered to have been drawn from separate populations (Snedecor and Cochran 1967).

The data illustrated in Table 3 were derived to determine whether any insight might be gained into the etiology of cardiovascular risk from the commonly measured serum chemistry or hematology variables. Partial correlation corrections for the combination of age and submarine service were performed for the data to uncover relationships between the risk factors and laboratory data that might be independent of the experimental situation. Though all correlations with possible statistical significance are shown in the table, only the most outstanding will be discussed. Others that seem unimportant now may eventually become important.

The positive correlations of the risk factors with hemoglobin and hematocrit levels apparently derived in large part from the fact that cigarette smoking increases hematocrit or hemoglobin levels through the relative anoxia produced by carbon monoxide and other noxious agents (Froelicher and Lancaster 1973). The carboxyhemoglobin levels in submariners and the relative concentration of this hemoglobin derivative in smokers and non-smokers in a closed submarine environment have recently been described by Bondi, Very, and Schaefer (1978). From a national survey involving 29,000 blood donors living in urban, suburban, and rural communities of the United States, a strong correlation has been reported between blood levels of carboxyhemoglobin and total blood hemoglobin concentrations. Tobacco smoking was the single most important factor for increased carboxyhemoglobin saturations observed (Stuart, Baretta, Platte, Stuart, Kalbfleisch, Van Yserloo, and Rimm 1974). The correlation data presented in Table 3 also suggest that leucocytes and neutrophils may be related to CHD risk through extent of cigarette smoking. The possibility of inhibition of chemotaxis of leucocytes by the components of cigarette smoke, particularly by the various aldehydes, has been suggested by Eichel and Shahrick (1969) and by Bridges, Kraal, Huang, and Chancellor 1977a; Bridges, Kraal, Huang, and Chancellor 1977b. It should also be noted that each of the serum proteins measured correlated negatively with the extent of cigarette smoking. In addition to its close relationship to cholesterol level, total risk also correlated highly in the submariners with various chemical components of the serum, including inorganic phosphate, urea nitrogen, uric acid, and alkaline phosphatase.

Among other relationships shown in Table 3 that should be considered are the significant correlations of blood pressure, pulse rate, cholesterol, and relative weight with hemoglobin and hematocrit levels. These correlations add confirmatory evidence that justifies the inclusion of hemoglobin in the calculation of CHD risk (Truett et al. 1967; Halperin et al. 1971). Similarly, the positive association of blood pressure, pulse rate, cholesterol, and relative weight with postprandial glucose levels supports the established association of diabetes with CHD risk (Gordon and Kannel 1971; Kannel et al. 1974). Though none of the subjects of this study, to our knowledge, was diabetic, a measurable prediabetic symptomatology was detected in the data (Tappan et al. 1979, this Supplement).

In most cases where risk was apparently associated with serum chemistry variables, i.e., with inorganic phosphate, urea nitrogen, uric acid, or alkaline phosphatase, the cholesterol level appeared to be the most closely related of the established risk factors. At this point, however, there is no reason to think that changes in cholesterol level are responsible for the fluctuations of other serum components. Blood pressure and heart rate, according to these data, are associated positively with serum protein levels, particularly total protein and globulin. These indicators of increased work load on the circulatory system, including the slight relative hemoconcentration, apparently reflect as well as contribute to the long-term accumulation of CHD risk in the subjects of this study. The negative correlation of urinary specific gravity with alcohol consumption may imply a slight renal dysfunction or perhaps an increase in thirst as a delayed aftereffect leading to increased water loading and excretion.

Though it is obvious that the variables used to estimate risk should correlate highly with risk, calculations were made to evaluate the relative contribution of the individual factors to overall cardiovascular disease risk in submariners. Correlations for these and other variables against risk are: smoking 0.272†; alcohol consumption 0.093‡; coffee 0.268†; hemoglobin 0.037; systolic blood pressure 0.095‡; diastolic pressure 0.230†; pulse rate 0.106†; relative weight 0.253†; and cholesterol 0.554† († = $P < 0.001$; ‡ = $P < 0.01$). These data leave little doubt that cigarette smoking, blood pressure, relative weight, and serum cholesterol levels make extremely important contributions to the risk of cardiovascular disease in submariners, as is true for the population in general (Friedman 1969; Kannel and Dawber 1972).

The above correlations and those shown in Table 4 suggest that total alcohol consumption is somewhat less closely associated with factors directly or indirectly related to CHD risk than is total coffee consumption. Because of alcohol's potential for damage to the liver and other organs however, it is expected that alcohol intake will be at least weakly associated with serum levels of SGOT and LDH (Damm and King 1965; Lieber 1975) and possibly with erythrocyte counts and serum protein levels.

Despite a significant association between coffee consumption and CHD risk, the relationship between the two variables appears to be complex. Although fasting and postprandial glucose, uric acid, cholesterol, and total protein, as well as the enzymes ALKP and SGOT, exhibit negative correlations with coffee intake, these factors generally correlate positively with total risk levels.

It appears possible that two different physiological effects of coffee consumption may be reflected by the data. First, the diuretic effect of large amounts of the beverage may exert at least a small influence on various serum components because of increased excretion rates. Second, the stimulant effect on the central nervous and cardiovascular systems of the alkaloid components of coffee is probably even more intimately associated with CHD risk in these personnel. Either because persons who are emotionally more tense tend to drink more coffee or because coffee consumption leads to increased tension, coffee drinking may be associated with CHD risk in the peculiar occupational circumstances of the subjects in this study. The susceptibility to CHD of individuals who are emotionally stressed, who feel a strong sense of urgency, or who are habitually over-competitive or hostile is fairly well established (Friedman 1969; Rosenman, Brand, Jenkins, Friedman, Straus, and Wurm 1975; Jenkins, Zyzanski, and Rosenman 1976; Glass 1977). The term type A personality has been used by Friedman and Rosenman (1959, 1974) to describe such individuals. Though it is not within the scope of this report to consider the psychological makeup of these subjects, there is considerable evidence to indicate that highly motivated personnel volunteer for submarine duty (Weybrew 1971). Several of our subjects may therefore be predicted to fall into the type A category.

According to Table 4, the level of alcohol use increases by a factor of about 1.5 between the youngest and the oldest groups of subjects, while cigarette smoking is heavier for men between the ages of 28 and 38 than for younger subjects and decreases again after about the age of 40. Mean coffee consumption increases four- or fivefold for subjects between their 18th and 48th years. Although the data are not adequate to establish a causative relationship between either alcohol or coffee consumption and risk of cardiovascular disease, there is an association with these habits that can only be attributed partly to their correlations with age. Table 2 indicates significant correlations of these habits with length of service even after the partial correlation effects of age have been eliminated. Regular alcohol consumption, even in what may be considered moderate amounts, has been extensively documented as a potential contributor to heart disease (Bing, Tillmans, and Ideka 1975; Gunnar, Demakis, Rahimtoola, Sinno, and Tabin 1975; Regan, Ettinger, Oldwurtel, and Haider 1975; Talbot 1975).

No absolute evaluation of the comparative risk for CHD in these subjects can be made with other groups because of the methodologic differences discussed earlier, the relatively small number of subjects in the older age groups, and the variety of methods used by various authors for reporting incidence of disease. Nevertheless, it is instructive to compare the apparent risks, as shown in Table 4, with the frequency of cardiovascular disease(s) observed in other studies.

From the tables of predictive risks derived from data of the Framingham study (Kannel 1974), it may be determined that for persons whose cholesterol values are 210 mg/dl, whose systolic blood pressures are 120 mmHg, who smoke, and who exhibit neither glucose intolerance nor left heart ventricle-electrocardiogram abnormalities, the expected probabilities of developing heart disease within 8 years are: 0.8/100 at age 35, 2.5/100 at 40, and 4.8/100 for 45-year-old men.

Data obtained for the prevalence of definite and suspected coronary heart disease for men in the United States in 1960–1962 indicated values of 0.3/100 at age 25–29, 0.5/100 at 30–34 years, 2.7/100 at 35–39 years, 2.0/100 at 40–44 years, and 6.8/100 at 45–49 years of age (Gordon and Garst 1965).

In the Western Collaborative Group Study, 8½-year occurrence rates of CHD, including angina pectoris, myocardial infarction, and acute myocardial infarction, were: 6.4/100 overall for subjects aged 39–49 years (8.9/100 for type A subjects, 4.2/100 for non-type A or type B subjects) (Rosenman et al. 1975).

The predicted 12-year occurrence rates for the submariners of our study, 2.1/100 at 33–38 years, 3.7/100 at 38–43 years, and 10.4/100 at 43–49 years, seem very comparable to the data from the other sources when corrected to the same time spans. The apparent frequency of currently detectable CHD in the subjects of the NCHS examination series (Gordon and Garst 1965) would, in fact, indicate somewhat higher rates of occurrence in the subjects of that survey compared to the other studies. Significant differences in approach, however, must not be overlooked.

Though according to the criteria used the men of the submarine service do not seem to be more vulnerable to coronary heart disease than males of other United States populations, they nevertheless appear to be at least as susceptible as other population groups. Since these men belong to a physically somewhat select subpopulation and must remain reasonably healthy to continue in the submarine service, it is apparent that to fulfill the health potential of this group completely, there is considerable room for improvement in habits, environmental components, and other factors that contribute to health. From the evidence presented in Table 4 that indicates that the total amount of cigarette smoking among men of the highest age groups seems to be decreasing somewhat compared to the younger men, it is possible to derive some encouragement from the fact that there may be changes in living styles that will lead eventually to a lowering of CHD risk. Improvement in this and other modifiable factors at younger ages could eventually lead to a better prognosis for the cardiovascular health of this population.

We are indebted to many investigators (see Tansey 1974) and to the submariners who participated in this study. The work was supported in part by Naval Medical Research and Development Command Work Unit MR041.06.01-0026.—*Manuscript received for publication May 1978; revision received August 1978.*

Tappan, D. V., L. W. Mooney, M. J. Jacey, and E. Heyder. 1979. Facteurs de risque cardiovasculair chez 1,017 sous-mariniers. Undersea Biomed. Res. Sub. Suppl.: S201–S215.—Plusieurs variables biochimiques, hématologiques, et psychologiques, significatives pour le pronostic des maladies dégénératives et surtout pour les troubles coronariens, sont étudies chez 1,017 sous-mariniers. Le pli cutané est plus épais chez ces sujets que chez la plupart des hommes d'un âge comparable. Le tissu adipeux total se trouve dans les limites du normal. La cholestérolémie, les cigarettes, le poids relatif, et la tension artérielle sont les facteurs directement responsables du risque cardiovasculaire de ce groupe. Quoique les sous-mariniers ne semblent pas plus exposés au risques cardiovasculaires que d'autres Americains, nous avons observé que le risque augmente avec la durée de service en sous-marin et en même temps avec l'âge. Une augmentation semblable de la cholestérolémie, indépendente de l'âge mais corrélée à la durée de service, a déjà été rapportée. Les corrélations ont été verifiées statistiquement. Quoiqu'on n'ait pas encore essayé de

prouver une rapport directe entre le risque cardiovasculaire et la consommation de l'alcool ou du café, des corrélations impressionantes ont été notées. Ces factéurs, avec la cholestérolémie, les cigarettes, et le poids relatif, doivent être considérés comme des facteurs modifiables chez nos sujets.

facteurs de risque cardiovasculaire	cholestérolémie
service en sous-marin	poids corporel
personnel militaire	consommation de l'alcool
cigarettes	tension artérielle
cafe	

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